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Valuing the visual impact of wind farms: An application in South Evia, Greece

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ABSTRACT

This study presents an application of the Contingent Valuation Method (CVM) for valuing the landscape externalities associated with the large-scale exploitation of wind power at the local level. The survey was undertaken in South Evia, Greece, which is a region with rich wind energy potential and a considerable number of wind farms in operation during the period of the study. The results showed that 57% of the households are not willing to contribute financially in order to implement interventions to mitigate the visual impact of wind farms. The mean willingness to pay per household to avoid the visual impact attributed to the installation of new wind farms in the area in question was estimated at €41.6/year taking into account all households of the sample. This estimate is relatively lower compared to the results of other relevant studies. As shown by a meta-analysis developed based on these studies, this is mainly attributed to the great recession in Greece and the reduced available income of households.
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Contents

1. Introduction

It is widely recognized that combating the negative effects of climate change constitutes one of the most significant challenges faced by the global community. The key role of renewables and particularly of wind power in tackling climate change has been acknowledged by several major studies completed recently [1,2]. In the European Union promotion of renewable energy sources and energy efficiency as well as the strengthening, expanding and improving the functioning of the emission trading system are the main pillars of the European policy to combat climate change. In this context, significant investments in new wind farms are included in almost all National Renewable Energy Action Plans undertaken by Member States in the Scope of Directive 2009/28/EC. Also, Pacala and Socolow [3] identified wind power as one of the key 15 technologies to solve the carbon and climate problem for the next half-century.

Even though wind energy is a pollution-free and infinitely sustainable form of energy, there is considerable concern over some environmental effects resulting from wind power development (see

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Nomenclature

CV	Contingent Valuation
CVM	Contingent Valuation Method
Q_i	quantitative and/or qualitative characteristics of the respondent *i*
RES	Renewable energy sources
S_i	socio-economic characteristics of respondent *i*
WTA	willingness to accept
WTP	willingness to pay
Y_i	the annual income of respondent *i*
ZTV	Zone of Theoretical Visibility

for example [4] as well as [5] for a comprehensive review). Criticism focuses primarily on the visual impact due to the installation of wind turbines and transmission lines, which results in the deterioration of the landscape and may harm the associated economic activities, namely tourism, real estate, etc. It is also worth mentioning that relevant concerns initiated reactions against wind energy that intensified in recent years as the number of installed wind farms and the size of turbines increased: nowadays the most common types of turbines have a nominal capacity of 2–3 MW, a tower height of 70–90 m and diameter blades of around 45 m. However, there are also cases where the local communities are positive towards the development of large wind farms [6,7].

The analysis of the visual impact associated with wind farms development presents significant methodological difficulties as it depends on turbine and site characteristics as well as on the level of exposure received by visual receptors. Several studies agree that the visual impact in a specific area increases with the size and number of wind turbines [8–10]. However, it is not clear whether a low number of large turbines is preferable to many smaller wind turbines or vice versa (for example Tsoutsos et al. [8] and Brusa and Lanfranconi [11] lead to contradictory results). The visual impact attributed to wind farms decreases with distance from dwellings or from the sea-coast in case of off-shore wind farms [12–16]. The materials and the color of wind turbines also affect the visual impact caused, which increases if the turbines contrast with the background [16]. In addition, the arrangement of wind turbines in the farm area as well as the spacing between them could also affect the overall human perception of annoyance, as can ground morphology, existence of neighboring buildings, vegetation and climatic conditions [11,16,17]. Last, as the perception of visual impacts is subjective it is also influenced by psychological factors. Individuals with a negative attitude towards wind energy are expected to find the visual impact less tolerable [18].

Several approaches can be implemented, independently or in combination, for analyzing and assessing the visual impact of wind farms. The most commonly used among them comprise [19,20,8,21]: (i) the Zone of Theoretical Visibility (ZTV) approach, which defines the land area from which a wind farm can be totally or partially visible (as the visual impact decreases with the distance, different zones of theoretical visibility can be defined representing different levels of visual burden); (ii) the estimation of appropriately designed indices, which incorporate specific parameters (e.g., population in the neighboring areas, number of wind turbines) influencing the visual impact of wind farms; (iii) field surveys and evaluation of the future changes in the landscape through photomontage, video-montages, etc; and (iv) monetization of the visual impact on the basis of appropriate environmental valuation techniques.

This paper aims at valuing the visual impact and the aesthetic degradation of the landscape associated with the large-scale wind power development at the local level by exploiting techniques of environmental economics. Attributing monetary values to environmental impacts associated with power generation technologies was widely used during the last two decades in the European Union and constitutes a powerful tool to comparatively evaluate alternative energy projects and technologies. Focusing on wind energy, environmental valuation techniques have been used for quantifying both the environmental benefits [22–24] and costs [25,26,13,27] associated with this specific power generation technology. This study presents an application of the Contingent Valuation Method (CVM) for valuing the landscape externalities attributed to wind farms installed in a Greek island, namely Evia. The implementation of the method was supported by a survey of the residents of the area in question, through the completion of an appropriately designed questionnaire with personal interviews. It should be noted that on the south side of the island of Evia, where the survey was undertaken, a significant number of wind farms are under operation (with a total installed capacity of 83.9 MW), while several new projects are planned. So the residents can evaluate the environmental impacts of wind farms on the basis of their own experiences. The findings of the analysis are comparatively evaluated with the results of similar studies conducted internationally, with a view to highlight the significance and the key parameters influencing the externality in question.

The structure of this paper is as follows: Section 2 presents a literature review of studies valuing the visual impact of wind farms. Section 3 describes the CVM used in this paper. Section 4 focuses on the application of the method, providing information on the study area, the design of the questionnaire, the survey undertaken, etc. Section 5 presents the selection of the appropriate econometric models and the basic results of the analysis. Finally, in Section 6, the main findings of the study are summarized and conclusions are drawn.

2. Review and meta-analysis of valuation studies

There is a growing number of studies, mainly in developed countries, aiming at valuing the visual impact and aesthetic degradation of the landscape caused by wind farms development. In this Section a review of this literature is given, with a view to undertake a meta-analysis, which may be used to easily approximate landscape externalities attributed to specific wind energy projects through benefits transfer.

2.1. Valuation techniques used

Various environmental valuation techniques have been used for monetizing the landscape externalities of wind farms, namely Contingent Valuation [28–30], Conjoint Analysis and particularly Choice Experiments [12,14,25,26,31,32], Hedonic Pricing [33,34], and Benefits Transfer [13].

The majority of the studies reviewed, exploiting either Contingent Valuation or Conjoint Analysis, estimate people's willingness to pay (WTP) for avoiding (e.g., through the exploitation of alternative energy sources) or eliminating (e.g., through the installation of wind farms in question in relatively isolated areas) the visual disamenities attributed to wind farms, while a rather limited number of studies (see for example [10,29]) focus on the willingness to accept (WTA) compensation for installing the wind farms in a specific area. Hedonic Pricing techniques usually explore the relationship between house prices and their proximity to wind

farms, with mixed results. For example, Heintzelman and Tuttle [33] found a significant negative impact on house price, while Hoen et al. [34] investigated about 7500 sales of single-family homes surrounding 24 existing wind facilities and concluded that neither the view of the wind turbines, nor the distance to those facilities have a statistically significant effect on sales prices. As the implementation of most of these approaches requires significant human and economic resources, benefits transfer approaches are also implemented using economic information captured at one place and time to make inferences about the economic value of environmental goods and services at another place and time (see for example Moran and Sherrington [13] for an implementation in Scotland).

2.2. Quantitative results

In the context of this review, we focus on 10 relevant studies that value landscape externalities attributed to wind farms through the willingness to pay / accept measure (Table 1). For a comparative evaluation, the estimates of WTP/WTA per household included in these studies have been reduced: (i) in 2010 U.S. dollars in order to bring all values onto the same time basis; and (ii) as percent of country's GDP per capita in the year of the study in order to bring all values onto the same income level. The main conclusions of the performed analysis are summarized in the following.

The visual impact of wind farms constitutes an important externality of wind energy, which should be taken into account in the energy planning and decision-making process. Based on the results of 7 studies, which included 30 separate estimates of WTP to avoid or mitigate the visual impact attributed to wind farms (both off-shore and on-shore), it was found that households would be willing to pay $\$_{2010}$ 0–671 per year to this end, while average value was determined at $\$_{2010}$ 117 per year and median at $\$_{2010}$ 53 per year. Expressing the findings of these studies as a percentage of the GDP per capita in the corresponding countries, estimates of

Table 1
Selected studies exploring in quantitative terms the landscape externalities associated with the development of wind farms.

No	Study	Country/region	Type of wind farms	Install capacity of wind farms	Valuation technique	WTP/WTA estimates
1	Ladenburg and Dubgaard [12]	Denmark	Off-shore	3600 MW	Choice experiment	The average WTP was estimated at €46, €96 and €122 per household and year for having the wind farms located at 12, 18 and 50 km from the coast in relation to a baseline case of 8 km. The WTP for the respondents who can see the wind farms from their residence or summer house was estimated at 280, 422 and 468 €/household/year for the corresponding distances.
2	Westerberg et al. [15]	France	Off-shore	108 MW	Choice experiment	The external costs of locating wind farms 5, 8 and 12 km from the shore are approximately €111, €46 and €0 per household and year on average across 3 latent class models.
3	Krueger et al. [14]	USA/Delaware	Off-shore	500 turbines	Choice experiment	The annual costs to inland residents were $\$_{2006}$ 19, $\$_{2006}$ 9, $\$_{2006}$ 1 and $\$_{2006}$ 0 per household for turbines located at 0.9, 3.6, 6 and 9 miles offshore. The cost to residents living near the ocean was $\$_{2006}$ 80, $\$_{2006}$ 69, $\$_{2006}$ 35 and $\$_{2006}$ 27 per household and year for the same distances between the wind farms and the coast. Finally, the cost to residents living in Delaware Bay was $\$_{2006}$ 34, $\$_{2006}$ 11, $\$_{2006}$ 6 and $\$_{2006}$ 2 per household and year for the same distances between the wind farms and the coast.
4	Groothius et al. [29]	USA/N. Carolina	On-shore	n.a.	CVM	The compensation required to allow the development of wind farms in the mountains of North Carolina using the WTA framework was estimated at $23 per household and year.
5	Dimitropoulos and Kontoleon [10]	Greece/Skyros & Naxos	On-shore	21–40 turbines	Choice experiment	A reduction in the number of turbines from 30 to 4, would imply a decrease in the required subsidy (estimated in the context of the WTA framework) of €1128 per household and year in Skyros, but only €282 per household and year in Naxos. The study assesses also other determinants of local acceptability of wind farms, but we consider here that the number of turbines to be installed is more relevant to the visual impact.
6	Meyerhoff et al. [32]	Germany/ Westsachsen & Nordhessen	On-shore	16–18 turbines	Choice experiment	The WTP for increasing the minimum distance between the wind farms and the residential areas from 750 m to 1500 m was estimated at €45.7 and €51.7 per household and year for Westsachsen and Nordhessen correspondingly.
7	Alvarez-Farino and Hanley [26]	Spain	On-shore	n.a.	Choice experiment Contingent rating	The estimated WTP for protecting the landscape was estimated at 6161 pesetas per household and year on the basis of the Choice experiment approach and 3378 pesetas per household and year on the basis of the Contingent rating approach.
8	Morran and Sherrington [13]	Scotland	On-shore	622.8 MW	Benefits transfer	The mean WTP for protecting the landscape was assumed equal to £69 per resident and year. This figure is adjusted on the basis of the numbers of turbines that are visible from each site and the distance between wind farms and residential areas.
9	Bergmann et al. [25]	Scotland	On-shore	160 MW	Choice experiment	Installing a large on-shore wind farm results in welfare damages, which are estimated at approximately £19.4–26 per household and year in the context of the WTP framework.
10	Navrud [28]	Norway	On-shore	Scenario A = 1.5 TWh Scenario B = 6.7 TWh	CVM	WTP for avoiding the environmental impacts of wind farms (mainly focusing on visual and landscape impacts) was estimated at NOK 855 per household and year for Scenario A and at NOK 1009 per household and year for Scenario B.

WTP range between 0–1.1% with the average estimated at 0.23% and median at 0.13%. The estimated WTP is lower for off-shore wind farms, where the average of 21 discrete values contained in 3 different studies estimated at $\$_{2010}$ 87 per household per year (0.16% of the GDP per capita), and substantially greater for on-shore wind farms, where the average of 9 discrete values contained in 4 different studies estimated at $\$_{2010}$ 186 per household per year (0.38% of the GDP per capita). As expected, the two studies valuing the environmental degradation attributed to the visual impact of wind farms on the basis of WTA, i.e. the amount of money that the residents are willing to accept as compensation for wind farms installation, lead to higher estimates of the externality in question, ranging from $\$_{2010}$ 24 to 1494 per household per year, which corresponds to 0.05–5.45% of the GDP per capita. Furthermore, the WTP for mitigation/avoidance of visual disamenities associated with both off-shore and on-shore wind farms seems to decline with the distance that separates them from residential areas. Fig. 1 summarizes the results of 9 studies that show the estimated WTP for mitigating visual disamenities attributed to wind farms categorized into different levels of proximity to residential areas. Specifically, four zones of proximity between wind farms and residential areas have been distinguished, on the basis of the zones of theoretical visibility commonly used to assess the visual impact [19]: (i) *zone* 1 extends to distances up to 2 km and wind turbines are dominant elements of the landscape; (ii) *zone* 2 extends to distances between 2 and 8 km and turbines are important elements of the landscape; (iii) *zone* 3 extends to distances between 8 and 12 km with the turbines being clearly visible but not intrusive; and (iii) *zone* 4 extends to distances between 12 and 18 km. In cases with no clear reference for distance proximity of wind farms in relation to residential areas, the corresponding willingness to pay estimates were classified either in zone 3 (for studies undertaken at local scale) or in zone 4 (for studies undertaken at regional or national scale).

Also, the WTP for mitigation/avoidance of visual disturbance attributed to wind farms seems to increase with the number of turbines and the total capacity of the wind farms. Last, surveys undertaken locally, in areas with specific plans for developing wind energy projects, lead to higher estimates of WTP per household compared to studies done at regional or national level.

2.3. Meta-analysis

In the context of this study a meta-analysis of the economic values attributed to the visual impact of wind farms and included in the reviewed studies was undertaken, with the aim to provide some preliminary and indicative estimates of the relative externalities associated with the development of specific wind energy projects. Various multiple regression models have been developed and tested in order to quantify the influence of various parameters on the economic value attributed to landscape externalities due to

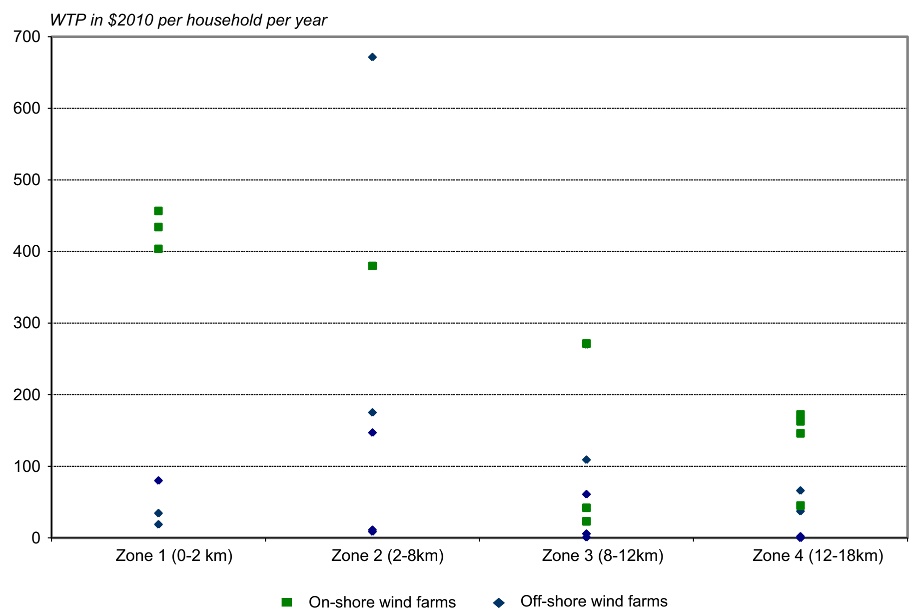

Fig. 1. Willingness to pay (WTP) for avoiding/mitigating landscape externalities attributed to wind farms in relation to the distance from residential areas.

Table 2
Values of the independent coefficients of the three models selected for quantifying the value of landscape externalities attributed to wind farms development. The WTP/WTA of households is estimated in $\$_{2010}$ in Models 1 and 2 and as percentage of the country's GDP/capita in Model 3.

Variable	Model 1		Model 2		Model 3	
	Coefficient	*P-value*	*Coefficient*	*P-value*	*Coefficient*	*P-value*
Constant	342.11	0.00019	247.41	0.02923	0.0083	0.00443
Z (installed in a zone 8–18 km from residential areas)	−230.01	0.00408	−218.88	0.00589	−0.0060	0.02283
P (installed capacity)	0.07	0.06259	0.08	0.03182	0.00001	0.37638
T (off-shore)	−228.88	0.01371	−236.15	0.01073	−0.0050	0.10093
V (willingness to accept)	360.56	0.01572	340.16	0.02163	0.0164	0.00163
S (local scale)			110.44	0.20436		0.00443
R^2 (%)	50.3		53		49.5	
Significance *F*	0.000238		0.000344		0.000298	

the development of wind farms and expressed either in $\$_{2010}$ or as percentage of the GDP per capita in the corresponding countries. The explanatory variables used in the two models finally selected comprise:

- One dummy variable (Z) aiming at representing the proximity of wind farms in question with residential areas. Z takes the value of 0 if the wind farm in question is located in a distance up to 8 km from residential areas and 1 in case it is located in a zone 8–18 km far from them. It is assumed that wind farms installed in distances greater that 18 km from residential areas do not cause any visual impact. In cases with no clear reference for distance proximity of wind farms in relation to residential areas, it was considered that $Z=1$.
- The installed capacity (P) of the wind farm in question, expressed in MW. As some studies provide the number of wind turbines considered in the survey, the installed capacity was calculated assuming that each turbine has a capacity of 2 MW, except one case in Greece, in which wind turbines of 3 MW were considered in accordance with the real data of the planned investment. Also, for studies indicating the penetration of wind energy in terms of electricity produced, the installed capacity was calculated assuming a load factor equal to 30%.
- One dummy variable (T) showing if the wind farm under consideration is off-shore (in this case $T=1$) or on-shore (in this case $T=0$).
- One dummy variable (V) indicating if the estimated economic values will be expressed in terms of willingness to pay for avoiding/mitigating the visual impact ($V=0$), or willingness to accept compensation for this burden ($V=1$).
- One dummy variable (S) indicating if the survey is undertaken locally ($S=1$), in areas with specific plans for developing wind energy projects, or at regional or national level ($S=0$). This variable is incorporated only in Model 2.

Table 2 presents the three models selected, the corresponding estimated coefficients and other indices related to the performance of the models. Models 1 and 2 use as dependent variable the WTP/WTA estimates in $\$_{2010}$, while in Model 3 the WTP/WTA estimates are expressed as percentage of the country's GDP/capita. The coefficient of determination (R^2) was estimated at 50.3% for Model 1, 53% for Model 2 and 49.5% for Model 3, meaning that the independent variables included in the models explain a corresponding percentage of the economic value attributed to landscape externalities of wind farms, which is quite satisfactory for this type of models based on meta-analysis of original studies. Furthermore, the signs of the calculated coefficients are reasonable. The estimated value of landscape externalities decreases with the distance between the wind farms in question and residential areas as well as for off-shore wind farms and increases with the installed capacity, in cases where a WTA measure is used and for households located in areas where new wind energy investments are planned.

3. The Contingent Valuation Method

The CVM is utilized for the economic valuation of environmental goods and services, which are not integrated into the market mechanism [35,36]. The monetary assessment of environmental goods and services is achieved through the development of a hypothetical market in which the potential customer is asked to complete a specialized questionnaire in order to reveal either his/her willingness to pay (WTP) for the improvement of the current state of the examined environmental good or service or his/her willingness to accept (WTA) a deterioration by receiving a compensation. The WTP is preferred in comparison with WTA, because it leads to more conservative estimates [35]. The simplicity of the method and the quantification of both use and non-use values of the examined environmental goods and services are considered as the most important advantages of the method. Although several criticisms have been raised regarding the reliability of the obtained results, several organizations, such as the National Oceanic and Atmospheric Administration of the U.S., considered the CVM as a very effective tool for the initial economic valuation of environmental goods and services and formulated specific guidelines for the implementation of the method aiming at increasing the reliability of the findings [35].

The main steps for the effective application of a CVM study comprise

I. *Clarification and delimitation of the valuation problem*: In this initial stage the valuation problem is defined by determining the environmental features or services sought to be assessed through the implementation of the method. In addition, the affected population is specified, in order to set the basis for determining the sample on which the survey will be performed.
II. *Design of the survey*: In this stage decisions on the size of the sample and the profile of the respondents are made. Furthermore, the available techniques for the conduction of the survey are evaluated selecting the most appropriate based on the peculiarities of each case study. The most commonly utilized techniques comprise the implementation of personal or telephone interviews, the completion of questionnaires via email or mail, etc.
III. *Design of the questionnaire*: A specialized questionnaire is developed consisting of the following basic parts:
   (a) introductory questions identifying the priorities and perceptions of the respondent regarding the examined environmental good or service;
   (b) provision of information regarding the current situation of the environmental good or service in question and clarification of any changes (positive or negative) expected due to specific interventions;
   (c) description of the payment vehicle for the elicitation of the amount that the respondents are willing to pay in order to improve or prevent the further deterioration of the examined good or service;
   (d) the economic question about the willingness to pay, which can be set in various formats such as open-ended question (how much are you willing to pay for the examined environmental good or service?), dichotomous choice questions, payment cards or bidding game; and
   (e) collection of the socio-economic characteristics of the respondents.
IV. *Conduction of the survey*: The respondents who will be asked to complete the questionnaires are randomly chosen from the reference population by applying appropriate statistical sampling techniques according to the design of the survey.
V. *Statistical analysis of the obtained results*: The analysis of the obtained results is performed by utilizing various statistical techniques. The design of the economic question specifies the type of the required statistical analysis. Specifically, in open-ended questions regression analysis is preferred for correlating the WTP with quantitative and/or qualitative aspects determining the perception and attitude of the respondents regarding the examined environmental good or service and their socio-economic characteristics.

The WTP is calculated with the following equation:

$$\mathrm{WTP}_i = f(Q_i, Y_i, S_i)$$

where WTP_i is the declared payment amount, and the factors considered to affect WTP_i, are namely Q_i: the quantitative and/or

qualitative indices characterizing perception of the respondents, Y_i: the specified income, and S_i: other socio-economic factors of the respondents.

The average WTP is calculated combining the coefficients of the regression model and the mean values of the parameters incorporated in the previous equation as independent variables. Alternatively, it is possible to use non-parametric statistical estimation techniques in order to estimate the WTP, such as the Kaplan–Meier technique. Finally, the total value of the examined environmental good or service can be estimated by applying the calculated WTP to the reference population.

4. Survey

As already mentioned this research aims at the economic valuation of the visual impact attributed to the large-scale exploitation of wind farms at the local level. The area of South Evia in central Greece presents a particularly rich wind energy potential attracting significant number of wind energy investments and was selected for conducting the survey as the people living in this area are already familiar with the potential disturbances generated by wind farms.

Specifically, in South Evia, wind farms with a total capacity of 83.9 MW were installed in the period of conduction of the survey, covering an area of approximately 56 ha. The population in the corresponding area, which is extended in more than 1000 km^2, is approximately equal to 40 thousand residents. It is also worth mentioning that apart from wind farms the citizens in the area under consideration are also familiar with the operation of conventional power plants, as in the reference area a natural gas-fired power plant with an installed capacity of 420 MW is already in operation. Additionally, in the same site oil-fired power plants were in operation until 2010.

The survey was conducted in two different periods, namely (a) July 2011 and (b) April–May 2012 via phone interviews. 200 questionnaires were completed in total (100 per period). The collected sample was representative of the demographic profile of the residents living in South Evia taking into consideration the age and the gender as recorded during the 2011 census. The proper stratification of the sample was ensured using appropriate criteria. A protocol was established for monitoring the composition of the sample on a regular basis over the survey in relation to the targeted stratification. In case of discrepancies, researchers applied specific guidelines for the selection of the participants with the appropriate profile that will result in improving the representativeness of the sample.

The developed questionnaire is presented in Appendix. It can be seen that the first part comprises 10 questions, which attempt to record the knowledge of the respondents regarding energy and environmental issues and the importance of renewable energy sources in the operation of power generation systems (relating environmental and economic aspects). Moreover, various other issues were examined such as respondents' attitudes regarding the potential environmental benefits and damages associated with the operation of the existing wind farms, respondents' involvement in the decision-making process for the effective setting and installation of wind farms and respondents' trust on various authorities, which are in charge of the licensing procedure for the installation of wind farms. Furthermore, the respondents were asked to specify how frequently they are coming in visual contact with the existing wind farms.

Then, the CV scenario was established, where the respondents had the opportunity to specify their willingness to avoid the triggered visual impacts from the development of additional wind farms in their region by paying an extra fee in their bill for electricity consumption in order to support the installation of more expensive renewable energy technologies in their region or to install the planned wind farms in remote areas. Among the available CV formats, the open-ended one was chosen, because it usually leads to more conservative estimates of WTP and the corresponding economic value of the examined environmental goods or services [37–39].

Finally, in the last part of the questionnaire, 9 questions were included to demonstrate the demographic and socio-economic characteristics of the respondents, allowing us to ensure the representativeness of the sample and to explore how a range of socio-economic factors can affect the willingness to pay.

5. Results and further discussion

In this Section the results of the survey are summarized.

The most widely known forms of energy used for electricity generation in Greece are found to be lignite (77% of the sample) and wind farms (75% of the sample). Only a small percentage of the respondents have chosen natural gas and other types of RES as sources for electricity generation (Fig. 2).

Most of the respondents (83%) stated that they were aware of the environmental impact of electricity production, while television and internet were specified as the main sources of information with percentages equal to 57% and 43%, respectively.

A 60% of the sample supported the further development of RES for eliminating the environmental impacts associated with fossil-fuelled power plants, even if this would lead to higher prices of electricity. On the other hand, 32% of the respondents were opposed to this proposal, while 8% preferred not to answer this question. Furthermore, 66% of the participants rejected the statement that electricity prices should be reduced irrelevant to the energy mix that will be used for power generation and the associated environmental deterioration, while 18% of them supported this statement (Fig. 3). These results clearly show that about two-thirds of residents were concerned about the environmental impact of electricity generation and are willing to pay higher electricity prices in order to mitigate these effects.

The majority of respondents (87%) supported the greater penetration of wind farms in the national energy system for environmental reasons, while 10% argued against this prospect. On the other hand, 33% of the sample claimed that the deployment of wind farms triggers environmental damages, while 48% of them disagree with this statement.

Regarding the importance of the environmental damages associated with the operation of wind farms, 47% of the participants specified the visual intrusion as important environmental impact, while damages in fauna and flora and noise were reported by 27% and 22% of the sample, correspondingly (Fig. 4).

Furthermore, 64% of the participants said that the decisions for the installation and siting of wind farms must be taken by experts, while 45% supported the involvement of citizens and 41% considered as important the participation of local authorities. On the other hand, the percentage of those declaring that the respective decisions must be taken from central government and private companies was relatively small. 53% of the sample specified their disappointment regarding their involvement in the decision-making procedure for the installation of wind farms in their region, while 38% were neither satisfied nor disappointed and only 9% were completely satisfied.

In the economic scenario questions, participants were asked whether they are willing to pay on a regular basis an additional financial amount in the electricity bill to avoid any further installation of wind farms in their area and thus additional aesthetic deterioration of the landscape. It was clarified that the

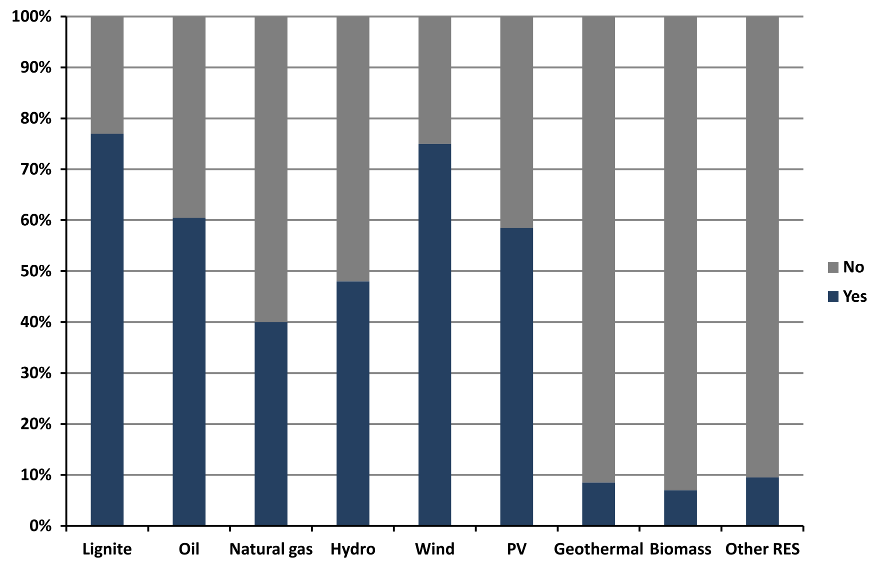

Fig. 2. Awareness of respondents regarding the utilized energy sources for electricity production in Greece.

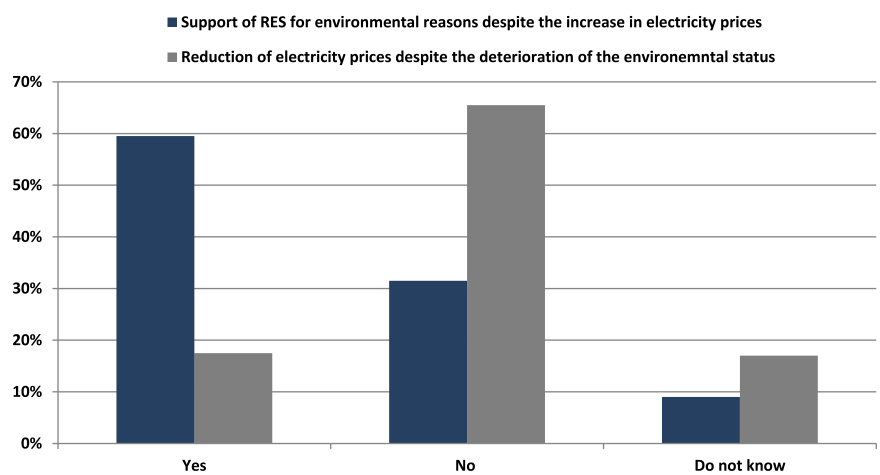

Fig. 3. Environmental concern of the respondents in relation to RES penetration and fluctuation of electricity prices.

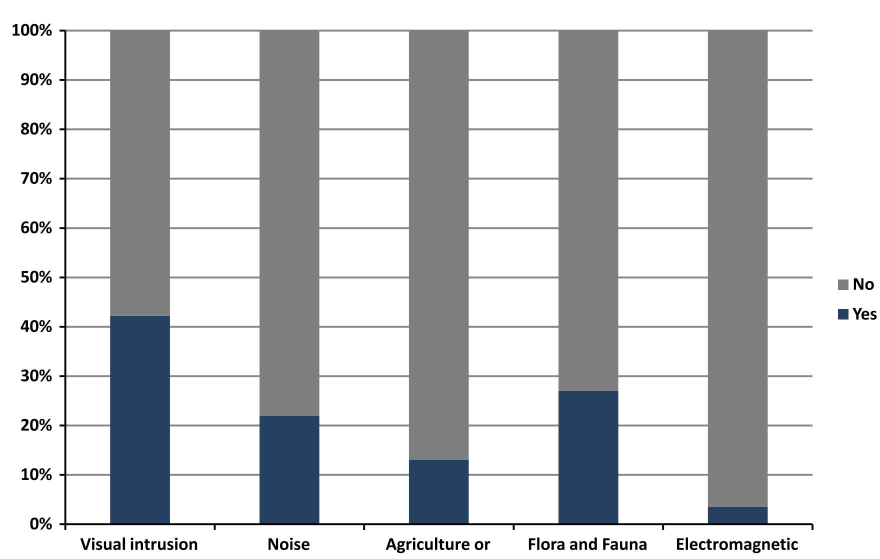

Fig. 4. Awareness of respondents regarding environmental impacts associated with wind farms development.

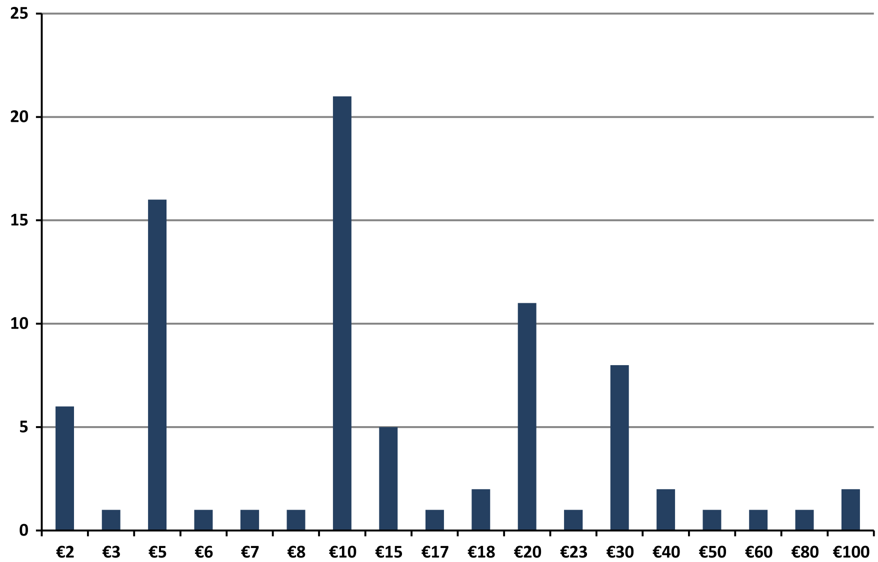

Fig. 5. Distribution of the amounts of the WTP (in €/2-months) reported by the respondents.

Table 3
Reasons reported by respondents to justify their unwillingness to pay for the implementation of interventions aiming to mitigate the visual impact of wind farms.

Variable	Respondents	Percentage (%)
Installation of wind farms does not result in degradation of the landscape	46	40
Wind energy is not considered a reliable source for electricity production	13	11
The hypothetical scenario seems to be unrealistic	15	13
I do not trust the Organizations conducting the survey	3	3
I do not trust central government	29	25
Other	8	7

Table 4
Results of the regression analysis.

Variable	Coding	Coeficient
Wind farms are utilized for electricity production	1: Yes, 0: No	−15.50***
Married as marital status of the respondent	1: Yes, 0: No	10.61***
Television as source of information	1: Yes, 0: No	−6.39*
Expenses for electricity consumption	€/2-month	0.07**
Pensioner as professional status of the respondent	1: Yes, 0: No	12.51**
Agree with the statement that the insecurity in the vicinity of a wind farm cannot be mitigated by any measure	1: Yes, 0: No	−11.07*
Reduction of environmental impacts through the increase of electricity price	1: Yes, 0: No	8.85**
Trust in central government	1: Yes, 0: No	−2.90*
Visual intrusion is an important environmental impact of wind farms	1: Yes, 0: No	−6.43*
Constant		22.12***
Observations	77	
Adjusted R^2	35.4%	
Mean WTP (€/2-month)	16.13	

* Statistically significant at 90% level.
** Statistically significant at 95% level.
*** Statistically significant at 99% level.

collected money will be used to fund the exploitation of other more expensive renewables or the installation of wind parks in remote areas. 43% of the sample agreed to contribute financially in order to reduce the visual intrusion impact associated with the development of new wind energy projects in the area in question, while 57% denied to pay. Fig. 5 presents a distribution of the amounts of the willingness to pay reported by participants. Also, Table 3 presents a distribution of the main reasons that led more than half of the participants refusing to pay a certain amount for mitigating visual impact.

For the statistical analysis of the collected data various multiple regression models were examined and evaluated. The model finally selected was developed taking into account only the part of the sample indicating a positive willingness to pay for mitigating the visual impact and is presented in Table 4. The estimated mean WTP of those who were willing to pay for avoiding an

additional deterioration of the landscape due to the installation of new wind farms was equal to €16.13 per 2-month and household. The correlation of WTP with the specific characteristics of the respondents led to the results presented below.

Married persons (*coefficient of variable* = 10.61) and pensioners (*coefficient of variable* = 12.51) appear to be more willing to contribute a higher amount of money for the implementation of measures in order to reduce the visual intrusion impacts. This can be explained by the fact that in general these population groups are characterized by a higher need for security and by a more conservative approach to life and the potential risks. In addition, the increased responsibility of married people, especially of those who have children, may influence their behavior.

Furthermore, respondents who are aware of the fact that wind farms are utilized for electricity production (*coefficient of variable* = −15.50) and those who report visual intrusion as an important environmental impact caused by wind farms development (*coefficient of variable* = −6.43) are willing to contribute less for the reduction of visual intrusion impacts. These trends can be explained by the fact that well-informed citizens, while acknowledging the visual impact as an important environmental impact of wind farms, consider the impacts on the landscape of rather minor importance in relation to the environmental impacts associated with other electricity generation technologies. On the other hand, it seems that people who are not well-informed about wind farms are more concerned regarding the impacts of visual intrusion.

In addition, respondents who believe that there exist measures to increase safety in the vicinity of a wind farm are more willing to pay a higher amount of money in order to reduce visual intrusion impacts (*coefficient of variable* = −11.07). It seems that this population group has a more positive attitude towards wind farms in relation to the others who believe that insecurity around wind farms cannot be mitigated. Moreover, someone, who utilizes television as source of information for the environmental impacts of power generation technologies (*coefficient of variable* = −6.39) and someone who trusts the central government for the setting of wind farms (*coefficient of variable* = −2.90) will pay less amount of money for the effective mitigation of visual intrusion impacts.

People with relatively higher expenses for electricity consumption are willing to contribute more for the reduction of visual intrusion impacts (*coefficient of variable* = 0.07). This tendency can be possibly explained by the higher income of the respective group of people. Finally, respondents who support the development of RES for the reduction of environmental impacts attributed to electricity generation despite the increase in the electricity price are willing to pay a higher amount of money for the adoption of measures in order to reduce visual intrusion impacts (*coefficient of variable* = 8.85). Obviously, this conclusion can be justified by the fact that the triggered environmental impacts of wind farms are significantly less in comparison with the corresponding damages from the fossil-fuelled electricity generation technologies.

6. Conclusions

This paper has implemented techniques of environmental economics for assessing the visual impact associated with the large-scale exploitation of wind energy, which shows a rapid deployment both in Europe and globally. Attributing monetary values to environmental goods, services and impacts seems to provide a powerful tool for integrating environmental concerns into the development process and relevant decision-making procedures. Particularly in energy planning problems, the exploitation of these techniques in the context of cost-benefit analysis helps illustrate those energy technologies and scenarios that maximize benefits to society, taking into account not only financial costs and benefits but also the associated environmental and social externalities. However, it is worth mentioning that the valuation of the visual impact attributable to wind farms does not replace the need for detailed environmental impact assessment studies for the development of wind farms in question and all necessary design measures to mitigate the negative effects caused to the landscape.

In the context of this study, the CVM was applied in order to estimate in monetary terms the visual impact associated with the large-scale exploitation of wind energy in South Evia, Greece, which is a region with a rich wind energy potential and with an installed capacity of wind farms reaching 83.9 MW in the period of survey. The results showed that 57% of the households are not willing to contribute financially in any attempt to mitigate the visual impact of wind farms, while for the remaining 43% of the sample a mean marginal WTP equal to €16.13 per 2-month and household was estimated for the current levels of wind energy penetration. On an annual basis, the WTP per household to mitigate visual impact of new wind parks in the area under consideration is estimated at €96.8 taking into account only the households that are willing to contribute financially for that purpose, and at €41.6 taking into account all households of the sample.

The results of the CVM study in terms of WTP for mitigating the visual impact of the wind farms is at the same order of magnitude but relatively lower compared to the findings of other relevant studies conducted internationally and presented in the literature review section. This can be attributed to (i) the fact that, as has been observed in other cases, the wind farms become acceptable elements of the landscape after some time from their development; (ii) the economic situation in Greece during the period of the survey and the restrictions in the available income; and (iii) uncertainties inherent to approaches based on benefits transfer. Using the 3 models derived from the meta-analysis of a number of surveys (see Section 2), the environmental cost attributable to the visual impact of wind farms in South Evia was estimated to range between €44–110 per household and year (for all households in the area). Models 1 and 2 lead to relatively higher estimates of the WTP (€89 and €110 per household and year correspondingly), while the results of Model 3 (€44 per household and year) are very close to those obtained from the CVM study. As this latter model takes into account the economic situation in each country, the relatively low values derived by the CVM study in Evia can be attributed to a large extent to the economic situation in Greece and the reduced income of the Greek households.

Extrapolating the estimated WTP to the total number of households (~14,332) and the total installed capacity of wind farms (83.9 MW with an average load factor of 30%) in the examined area, it was calculated that the marginal external cost associated with the visual degradation of the landscape due to the existing wind farms amounts to 2.71 €/MWh. In conclusion, the visual impact of the relatively large-scale exploitation of wind energy is an important externality but considerably lower compared to external costs caused by fossil-fuelled power generation technologies. Therefore, the large-scale exploitation of wind energy and the substitution of electricity generated by fossil fuels imply significant environmental benefits that can be valued in monetary units.

Appendix A. Questionnaire for the economic assessment of the visual intrusion impacts of wind farms in the region of South Evia

Number of questionnaire ☐☐☐

Hello. I am a postgraduate student and within the context of my thesis it is important to write down your opinion about the visual intrusion impacts attributed to wind farms. Would you like to help me with this survey?

Please note that there are no right or wrong answers. We are just trying to record the views of households on the subject of our research.

1. Please refer the energy sources that are utilized for electricity production in Greece.

☐ Lignite
☐ Oil
☐ Natural gas
☐ Hydro energy
☐ Wind energy
☐ Photovoltaic energy
☐ Geothermal energy
☐ Biomass
☐ Other RES

2. Have you ever heard or read anything about electricity generation and the potential impacts on the environment?
   If yes, please refer your sources of information:

I. TV... ☐
II. Radio.. ☐
III. Newspapers or magazines... ☐
IV. Friends... ☐
V. Internet... ☐
VI. Other (Please specify): .... ☐

No I have not heard or read anything relative ☐

3. Please specify if you agree or no with the following sentences:

	Yes	No	I do not know
Environmental impact associated with electricity generation should be reduced through the highest penetration of RES, even if this will lead to an increase in the price of electricity.			
The price of electricity should be reduced, even if this lead to an increase of the environmental impacts associated with electricity generation.			

4. Electricity production in Greece is based on fossil fuels and especially lignite. Would you support increasing the share of electricity from wind farms for environmental reasons?

Yes	
No	
I am not sure	

5. Do you believe that the wind farms trigger negative impacts to the environment?

Yes		Question 5[a]
No		
I am not sure		

5[a] Please refer the main environmental impacts associated with wind farms development. You can specify more than one options.

1. Visual intrusion
2. Noise
3. Negative impacts on agriculture and livestock
4. Negative impacts on flora and fauna
5. TV and radio signals' disturbances
6. Other (Please specify) …………………………………………………..

6. Do you have visual contact with the wind farms? If yes, please specify the frequency.

No	
Yes	1. Daily 2. Once a week 3. Once a month 4. Rarely

7. Please specify the stakeholders that in your opinion should be involved in the decision-making process for the installation of wind farms. You can specify more than one option.
   1. Experts
   2. Local government
   3. Central government
   4. Citizens
   5. Companies
   6. Other (Please specify) …………………………………………………………..

8. Please evaluate the level of your involvement into the decision-making procedure for the installation of wind farms in your area.
   1. Very dissatisfied
   2. Dissatisfied
   3. Neither dissatisfied nor satisfied
   4. Satisfied
   5. Very satisfied
   6. I have not participated

9. Who from the following stakeholders should reassure the required levels of security from the operation of wind farms?
   1. The company which is responsible for the operation of the wind farm
   2. Central government
   3. Local government
   4. Citizens
   5. No stakeholder can reassure the required levels of security.
   6. Other (Please specify) ……………………………………………………………..

10. Please evaluate your level of trust of the following stakeholders.

		No trust	Low trust	Medium trust	High trust	Very high trust	I do not know
1	Local government	1	2	3	4	5	0
2	Media	1	2	3	4	5	0
3	Central government	1	2	3	4	5	0
4	Energy Regulatory Authority	1	2	3	4	5	0
5	Environmental associations	1	2	3	4	5	0
6	Companies	1	2	3	4	5	0

Economic question

Greece, in order to meet its obligations arising from the European energy and climate policy, commits to increase the share of electricity produced by RES until 2020 contributing to the reduction of air pollution and GHG emissions. To this end, a measure promoted by the competent authorities is the further utilization of wind energy and consequently new wind farms are planned to be installed in your area. You have the option to pay on a regular basis an additional amount of money in the electricity bill for mitigating the visual impact attributed to wind farms, through the promotion of other more expensive RES technologies in your area or for the installation of wind farms in relatively remote areas.

11. How much money are you willing to pay in your bi-monthly electricity bill for this purpose;

Please specify:___________ €

12. Please specify how much money do you pay for your bi-monthly electricity bill?

€

13. *(In the case of unwillingness to pay including zero amount of money)* Can you specify the main reasons for your unwillingness to pay?
    1. The installation of wind farms does not result in degradation of the landscape.
    2. Wind energy is not considered a reliable source for electricity production.
    3. The hypothetical scenario seems to be unrealistic.
    4. I do not trust the organizations conducting the survey.
    5. I do not trust central government.
    6. I would like to avoid the visual intrusion impacts but my income is low and therefore I cannot contribute financially to this end.
    7. Other (Please specify) ……………………………………………………………..

<u>Demographic characteristics</u>

In this part of the questionnaire, we would like to give us some information about your household. These questions will help us to be sure in the end of the survey, that we have interview the cross section of the population.

1. Please specify your gender: Male ☐ Female ☐

2. Please specify your age:_______

3. Please specify the location of your permanent residence:_____________________________

4. Please specify your marital status.

    Single………………………………… ☐

    Married………………………………… ☐

    Windowed…………………………….. ☐

    Divorced……………………………… ☐

5. Please specify the number of your family members with their corresponding age.

    Under 18 years old…......... ☐

    Between 18-65 years old..... ☐

    Over 65 years old…........... ☐

6. Please specify your educational level.

- I have not attended school .... ☐
- Graduate of primary education........... ☐
- Graduate of secondary education........ ☐
- Graduate of university...................... ☐
- MSc/ MBA or PhD............................... ☐
- Student.. ☐

7. Please specify your occupation.

- Private employee. .... ☐
- Unemployed... ☐
- Pensioner... ☐
- Housewife.. ☐
- Student.. ☐
- Other (Please specify) : ______________________

8. Please specify the area of your home; [m^2]

9. Please specify which of the following categories represents the annual gross income of your family.

	Less than 6000 €
	6000 € – 12000 €
	12000 € – 18000 €
	18000 € – 24000 €
	24000 € – 36000 €
	36000 € – 48000 €
	48000 € – 60000 €
	More than 60000 €

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